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The Aquatic Environment

Properties of Water

- Density
- Specific Gravity
- Hydrostatic Pressure
- Buoyancy
- Refraction
- Surface Tension

Therapeutic Application – Density & Specific Gravity

- Body Density & Composition will affect aquatic posture and ability
Therapeutic Application – Hydrostatic Pressure

- Evens tactile input
- Assists blood & lymph return to the heart and thus reduces edema
- Strengthens inspiratory muscles and assists with exhalation (60% harder to inhale)
- Decreases perception of pain

Therapeutic Application – Buoyancy

- Reduced Compression and Weight Bearing Stress on Immersed Joints
- Reduces the risk of falling when balance & strength are challenges
- May reduce or eliminate pain with movement
- May assist with prevention of atrophy and assist with speed of rehabilitation
- May increase intensity or provide support

Becker, Biophysiologic Aspects of Hydrotherapy (pg 25)
Center of Buoyancy vs. Center of Gravity

- **Center of Gravity**
  - Point at which all force movements are in equilibrium
  - Location -

- **Center of Buoyancy**
  - Center of all buoyant force movements
  - Location -

Buoyancy Principals

- **Buoyancy Assisted**
  - Any movement toward the surface

- **Buoyancy Resisted**
  - Any movement away from the surface

- **Buoyancy Supported**
  - Floating / supported movements on the surface of the water

Therapeutic Application – Refraction

- Patient and Therapist Observation may be misleading

The Broken Pencil Observation
- Pencil placed in exact center of container.
- Pencil placed to the left of the center.
- Pencil placed on far left side of container.
Therapeutic Application – Surface Tension

The change in viscosity and breaking the tension of the surface of the water can result in ballistic movements and torque for the joints involved.

Properties of Water in Motion

3 Major determinants of water motion
1. Viscosity
2. Turbulence
3. Speed

Properties of Water in Motion - Flow Motion

Laminar / Streamline Flow
- Occurs when water is moving slowly and all molecules are traveling in the same direction

Turbulent Flow
- Friction of molecules or object in the path of water cause molecules to move in opposite directions causing eddy currents and surface disruptions
Properties of Water in Motion - Flow Motion

- **Eddy Currents**
  - Currents that swirl like whirlpools and appear to flow in the opposite direction from the predominate water flow
- **Viscosity**
  - The internal friction between molecules in a fluid causing turbulent flow patterns and greater energy cost

Properties of Water in Motion - Drag Contribution/Force

- The resistive effects of water against a body or object moving through it
  - Effective by:
    - Frontal SA
    - Velocity
    - Shape of the Object

Properties of Water in Motion

- **Bernoulli Effect**
  - Internal fluid pressure is inversely proportional to the stream velocity; when the stream velocity increases, the stream pressure decreases
- **Viscous Resistance**
  - Resistance resulting from the viscosity of a fluid increases with the velocity, shape and size of an object or body moving through it
Kinetics & Water

Newton's Laws:
1. The Law of Inertia
2. The Law of Acceleration
3. The Law of Reaction

LAW OF INERTIA:
An object will remain at rest or in motion with constant velocity unless acted on by a net external force.

- **Force of gravity** on object generates its weight.
- **Force of inertia** on an object generates its resistance to change in direction and speed.

LAW OF INERTIA

- **Total Body Inertia**. When traveling, it requires more effort to start, stop, or change direction of the body.
- **Water's Inertia**. Changes in travel that require additional effort to reverse the water's motion.
- **Limb Inertia**. Requires effort to overcome inertia to move limbs.

*These interact & work together to alter intensity!*
LAW OF INERTIA Summary

- “CHANGE”
  - Decrease intensity - more repetitions, same movement in place.
  - Increase intensity - fewer repetitions, more combinations and travel.

  Consider participants & acoustics when designing choreography changes!

LAW OF ACCELERATION

The reaction of a body as measured by its acceleration is proportional to the force applied, in the same direction as the applied force, and inversely proportional to its mass.

- Adding more force or muscular effort increase intensity of exercise.
- Speed not changed or increased.
- **Same cadence is maintained,** but more force is applied to the movement.

LAW OF ACCELERATION

- Push harder off the bottom of the pool to spring up higher or lift the knees more forcefully. *(Involves acceleration and the effects of action/reaction)*
- Cue to “push harder”, “take bigger steps”, “jump higher”, “lift your knees” or just “use the water”.
- Keep same cadence & alternate through “hard” and “easy” sets - *Work the Water*. 
LAW OF ACCELERATION Summary

- **“FORCE”**
  - Decrease intensity- apply less force against pool bottom or water’s resistance.
  - Increase intensity- apply more force.

  *Going faster will increase intensity in the water, but is NOT RECOMMENDED if ROM or alignment is compromised.*

LAW OF ACTION / REACTION

For every action, there is an equal and opposite reaction.

- Aquatic exercise provides an excellent example due to viscosity of water.
- Actions of the arms and legs
  - Working with each other - **Assisting**
  - Working in opposition - **Impeding**

LAW OF ACTION / REACTION

- Combining arm & leg movements more challenging in the water than on land.
  - If arms work against the legs - more resistance created & more force required.
  - If arms assist the movements of the legs - workload reduced.
ACTION/REACTION Summary

- “ASSIST or IMPEDE”
- Decrease intensity - Use assisting arms and legs.
- Increase intensity - Use impeding arms and legs.
  *Impeding arm or leg patterns should never sacrifice form or alignment.*

Properties of Water in Motion-Therapeutic Application

- Motions that prevent drag shielding increase work effort
- Increasing turbulence, SA, and/or velocity increases effort
- Very beneficial for individualizing exercise in a group setting

Newton’s Laws – Therapeutic Application

- Inertia challenges balance, starting, stopping and direction changes
- Acceleration forces also call for good “grounding” and proper body mechanics
- Use reaction forces by employing arm motions to assist or resist movement
- Very useful in individualizing and modifying intensity levels
Kinetics & Water

- Compression
- Distraction/Traction
- Friction

Thermodynamic Properties of Water

- Specific Heat
- Thermal Energy Transfer
  - Conduction, Convection & Radiation
  - Heat Transfer

Thermodynamic Properties of Water – Therapeutic Applications

- Transfer increases with velocity
- Thermal properties of water relieve pain
  - Heat vs. cold
Water can be used for rehab purposes in a WIDE RANGE of temperatures…from cold to hot, water provides a very useful medium for therapy!

Physiologic Effects of Water – CV System

- Hydrostatic Pressure assists venous return to heart
- Central volume increases by 60%
- Cardiac volume increases by 25%
- Mean stroke volume increases by 38%
- Heart rate drops by as much as 18%
- Cardiac output increases by 35%

Therapeutic Applications

- Water exercise is aerobically efficient and may be an ideal CV conditioning medium
- THR 10-17 bpm lower than expected on land
- Muscle blood flow more than doubles with immersion
Increased Central Blood Volume

Water Immersion to chest or Higher
Hydrostatic Pressure
Venous Compression
Lymphatic Compression
Increased Central Blood Volume
Venous Compression
Venous Compression
Venous Compression
Venous Compression
Venous Compression
Venous Compression
Venous Compression
SV Increases
CD Increases
CV Changes After Immersion

What Should Practitioners Recommend?

- The Majority of the Literature agrees that heart rate will decrease with immersion by 2-15 bpm
- To Test is Best!

Basic Formula vs Kruel Formula

- Basic formula:
  - 220 - age - RHR = X
  - (X)(% workload) + RHR - 17 = ATHR
- Kruel Formula:
  - 220 - age - RHR = X
  - HR_{LAND} - HR_{WATER} = Aquatic Factor (AF)
  - (X)(% workload) + RHR - AF = ATHR
Physiologic Effects of Water – Pulmonary System

- Immersion makes breathing more difficult resulting from:
  - Hydrostatic pressure on the chest & abdomen
  - Increased thoracic blood volume
- Creates a training effect for inspiratory muscles
- Total work of breathing for a tidal volume of 1 L increases by 60% with immersion to the neck

Becker, Biophysiologic Aspects of Hydrotherapy (pg 41)

Pulmonary System – Therapeutic Application

- Breathing impairments will find immersion difficult but immersion has proven to assist in these conditions
- Immersion and exercise performed in deeper water will train the respiratory system to greater capacities and efficiency

continued
Physiologic Effects of Water - Renal System

- Immersion affects the renal system both mechanically & hormonally.
- Increased central blood volume increases renal blood pressure resulting in increased urine output to regulate systemic blood pressure downward.
- ADH production drops and renal stimulation hormone production increases, urine output is increased, with added output of sodium and potassium and increased creatine clearance.
- Renal response increases with depth and temperature.

Renal System - Therapeutic Application

- Diuretic effects of immersion in water can help regulate blood pressure downward.
- Diuresis without rehydration can cause dehydration & the thirst mechanism is hindered with immersion.
Physiologic Effects of Water - Muscular System

- Soft tissue compression promotes extracellular fluid transport to venous blood capillaries and lymphatic vessels reducing edema.
- Temperature and venous assist promote increased blood supply to muscles, improving oxygen delivery and improving removal of muscle lactate and other metabolic wastes.
- Muscles relax due to improved blood supply, water temperature, and decreased sympathetic nervous system activity.

Physiologic Effects of Water - Muscular System

- Spastic muscles may be somewhat inhibited due to decreased gamma fiber activity, which decreases muscle spindle activity.
- Above effects prepare soft tissues for more effective mobilization.
- Muscle relaxation reduces joint compression forces.

VARIATIONS IN MUSCULAR CONTRACTION
Isotonic Muscle Actions -
Involve movement at the joint:

Concentric = shortening contraction

Eccentric = lengthening contraction

Gravity and Muscle Action

Gravity Resisted = away from center of earth = Concentric

Gravity Assisted = toward center of earth = Eccentric

Submerged Movement

- Gravity still involved, but reduced by opposing vector of buoyancy

- Resisted in all planes of movement and in all directions of movement by the water’s viscosity and drag properties
Submerged Movement

- Without added resistance equipment, both muscles perform **concentric** actions.
- One reason water can help promote muscle balance...not necessary to reposition the body or change exercises.

Buoyant Equipment

Specific to the aquatic environment:

- Buoyancy Assisted = toward water’s surface = **Eccentric**
- Buoyancy Resisted = toward bottom of the pool = **Concentric**

Weighted Equipment

- Muscle action in the water similar to land
- As long as equipment is denser than water and sinks, it will be affected by gravity
Weighted Equipment

Gravity Resisted =
toward water’s
surface =
Concentric

Gravity Assisted =
toward bottom
of pool =
Eccentric

Weighted versus Buoyancy

- Due to body structure, when standing in the water:
  - Deltoids, abductors, iliopectos & erector spine difficult to target with buoyant equipment
  - Adductors, latissimus dorsi, rectus abdominis & gluteus maximus difficult to target with weighted equipment

Drag Equipment

- Resisted in all planes of movement
- Muscle action primarily concentric in all directions of movement
Drag Equipment

- Same muscle action as using no equipment, however resistive force is magnified
- Increases surface area or turbulence
- Some can be cumbersome and limit ROM – but still one of most popular choices
- Feels consistent with natural movement of water
- ALL types of equipment increase drag to some degree!

Contraindications & Precautions of Aquatic Exercise

Contraindications

- Open/Draining Wound
  - Smaller wounds can be covered with an occlusive bandage/dressing
- Severe Burns
- Fever Over 100 degrees
- Vomiting
- Bowel Incontinence

CONTINUED
Contraindications
- Cardiac Failure
- Unstable BP
- Blood Infection
- Deep Vein Thrombosis
- Uncontrolled Epilepsy
- Renal Disease or Dysfunction
- Severe UTI

Contraindications
- Refluxive Ureter
- Menstruation without internal protection
- Severe Respiratory Infection
- Severe or Contagious Dermatological Disorders
  - Impetigo
  - Draining herpes
  - lice

Contraindications
- Tracheostomy
- Non-Tunnel Catheters
  - PIC
  - Intrasil
  - Supra-pubic
Contraindications

- Compromised Immune Function
  - HIV (under 200 T cell count)
  - Chemotherapy
- Respiratory disease with VC < 1500 cm³
  - Careful screening with VC < 1L

Precautions

- Small Open Wounds
  - Cover with Tagaderm
- Uncontrolled High/Low BP
  - Moderate HTN okay
  - Monitor Low BP closely
- Cardiac Conditions
  - Angina
  - arrhythmias

Precautions

- Intravenous Lines
- Intolerance to Fluid Loss
  - With some kidney disorders
- Heat Intolerance or Poor temperature Regulation
  - MS
  - SCI

continued
Precautions

- Excessive Skin Sensitivity
  - Especially to Chlorine or Bromine
- Ear Infections or Perforated Ear Drums
- Cerebral Hemorrhage
  - Wait a least 3 weeks after bleeding ceases
- Vertigo or Dizziness
- Absence of cough reflex

Precautions

- Medication Side Effects
- High Risk Pregnancy
- Behavior Problems
- Extreme Fear of Water
- Dysphasia
  - Caregivers may be able to assist with communication

Precautions

- Hyponatremia
  - Water intoxication
- Serious Debilitation or Deconditioning
- Autonomic Dysreflexia
  - May lead to seizures, stroke, abnormal heart rhythms, or even death
- Orthopedic Precautions
The Pool Is Indicated When...

When Tone is a Restrictive Factor For:
- ROM
- Strengthening
- Muscle Re-Education
- Posture
- Gait Training

The Pool Is Indicated When...

When Tone is a Restrictive Factor For:
- Mobility
- Transfers
- Balance Coordination
- Pain free tolerance to movement
- Hyper / Hypotonus is better addressed in the water
- Speech production

The Pool Is Indicated When...

When Pain is a Restrictive Factor For:
- ROM
- Strengthening
- Muscle re-education
- Postural Alignment
- Sensory Deviation
- Gait Training
- Conditioning
The Pool Is Indicated When...

- When Weight Bearing Status Restricts:
  - Standing
  - Gait Training
  - Conditioning
  - Joint Integrity will not tolerate resistive work against gravity

The Pool Is Indicated When...

- When Excessive Weakness Restricts:
  - Trace to poor muscle contractions
  - Strengthening
  - PROM / AROM ranges are greater and more consistent in the water

The Pool Is Indicated When...

- When Preclusion of Land Exercise is a Factor:
  - Too painful on land
  - Joint integrity is poor
  - Post surgery
  - Partial weight bearing precautions
Thank you for your interest in the Aquatic Environment!

I hope you enjoyed the presentation

Questions???

Lori A. Sherlock
lsherlock@hsc.wvu.edu